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Improve the Impact Strength of Polymer-Polymer Composites after Post Curing

Sana S. Hameed ,*[1]Besma M. Fahad[2]

[1.] *MSC. Student, Department of Materials Engineering, College of Engineering, University of AL-Mustansiriyah, Baghdad ,Iraq.*

[2.] *ASSt. Prof. Department of Materials Engineering, College of Engineering, University of AL-Mustansiriyah, Baghdad ,Iraq.*

ABSTRACT: *Two sets of polymeric composites were formed. The first set included epoxy as matrix , while the second set included unsaturated polyester UP as matrix. The two sets were reinforced with Polyvinyl Chloride PVC at different volume fractions. Each set was formed into two groups: one was allowed to cure at room temperature and the other was post cured at 40°C for 4hr . The percent of reinforcing and the curing temperature can affect the behavior of composites. The epoxy composites is the highest in hardness and impact strength than unsaturated polyester composites after reinforcing with thermoplastic material PVC. The best results were reached after post curing at 40°C for 4hr .*

Keywords: *epoxy, unsaturated polyester, polyvinyl chloride (PVC), Impact, hardness.*

I. INTRODUCTION

Many of our technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloy, ceramics and polymeric materials. A composite is a multiphase material that is artificially made and chemically dissimilar and separated by distinct interface. One of these phases is termed the **matrix** which is continuous and surrounds the other phase often called the **reinforcement** phase which consists of three main divisions: particles, fibers and structure, which should be much stiffer and stronger than the matrix. Polymeric composite is considered the earliest type of composite that is used in the greatest diversity of composite applications as well as in the largest quantities in the light of suitable ambient temperature properties, ease of fabrication, low density, good ductility and low cost. Polymeric materials could be classified according to behavior with rising temperature in to (Thermosets, Thermoplastics) [1, 2, and 3].

Upon heating thermoplastic materials soften and melt, removal of the heat results in hardening, while with a thermosets, heat causes the material to char and decompose with no softening. thermosetting polymers are stronger and stiffer than thermoplastics. thermoplastics offer the possibility of being heated and then pressed into to the required shapes, an example of thermoset polymers is epoxy and unsaturated polyester [4, 5], while polyvinyl chloride (PVC) is an example of thermoplastic materials. It is considered one of the most widely used plastics in the vinyl family. PVC is a very durable and long last construction material, which can be used in a variety of applications, either rigid or flexible. Its good impact strength and weatherproof attributes make it ideal for construction products [6, 7].

II. AIMS

Study the effect of PVC particles addition in different percentages to the epoxy and unsaturated polyester as matrices on the hardness and impact strength, also find out the effect of post curing on the properties of composites.

III. EXPERIMENTAL WORK

3.1**Materials**

1**Matrix I**

The Unsaturated polyester (UP) was chosen to be the resin of matrix I which was transparent liquid. The accelerator and the hardener of the Unsaturated polyester were Cobalt Naphthalate and Methyl Ethyl Keton Peroxide (MEKP) respectively in a liquid state.

2. Matrix II

Quickmast epoxy 105 (DCP) Company /Jordan. was chosen to be the resin of matrix II . Specific gravity and viscosity of this epoxy resin were 1.04 and 1 poise respectively. The ratio between resin and hardener for this epoxy is 1:3 by weight .

3. Reinforcement

PVC polymer (polyvinyl chloride) which was in a solid state as fine powder (75-300μ). The density of PVC is 1.3 (g/cm^3).

IV. EXPERIMENTAL PROCEDURE

The basic processing procedure was started by preparing the materials that are necessary to form composites (resin, reinforcement, mold, mold release agent…etc.).The materials were weighed by a sensitive balance to weigh the proper quantities that are needed to produce the specimens.

A rectangular metal mold (55mm length,10mm width , 6 mm thickness) was prepared. The mold was designed to have removable base to facilitate the demolding of the specimens after applying a release agent to the mold's internal surface. The mold was clean after every time it had been used.

A hand lay-up process was chosen to form two sets of composite's specimens ; the first one included unsaturated polyester (UP) as matrix and the second one included epoxy as matrix, each set was reinforced with polyvinyl chloride (PVC).

In the first set the unsaturated polyester was mixed with the accelerator (Cobalt Naphthalate) at 0.5% which give it a pink colour after it was transparent , then the hardener(MEKP) is mixed with them at 2%; while in the second set the epoxy was only mixed with the hardener (MEKP) at 1:3% by weight .

Careful should be made in adding the hardener at specific percentage to keep the reaction under control because its an exothermic reaction and to prevent any internal stresses or bubbles can occur.

After the homogeneity is achieved in the polymer, the reinforcement is added at different weight to obtain different volume fractions to the both sets.

Thoroughly mixing is recommended to achieve the best distribution in the formed composites.

The composite's specimens that are formed in both sets are allowed to cure at room temperature for 24 hr to reach complete hardening. After curing the specimens are demolded and weighed , then the same procedure are repeated again to produce a second group of composite's specimens; the only difference from the first group is that the specimens were post cured at 40° c for 4 hr.

V. HARDNESS TEST

Hardness is the characteristic of a solid material expressing its resistance to scratching, cutting, wear, indentation, penetration and machinability .This test was performed by using shore hardness (D) and according to (ASTM D 2240) at room temperature shows. The device used in this test is shown in figure (1 .(The hardness of polymer specimens was found by taking seven reading on each side of the specimen.[8] Material hardness generally depends on the type of interatomic or intermolecular bonds, surface condition, temperature, and others. Hardness increases with decreasing particles size. Hardness covers

- Elasticity, plasticity. - Strength and strain.
- Brittleness/ ductility and toughness

The most widely used device is a shore hardness meter. The shore hardness is measured with an apparatus known as a durometer and consequently is also known as "durometer hardness". The term durometer is often used to refer to the measurement as well as the instrument itself. Durometer is typically used as a measure of hardness in polymers ,elastomers, and rubbers. Hardness value is determined by the penetration of the durometer foot in to the sample. Because of the resilience of rubbers and plastic the indention reading may change over time. So the indention time is sometimes reported along with the hardness number [9].

Figure (1): The digital durometer pocketsize model for shore D hardness testing "digitat hand-held hardness tester".

6. Impact Test

It is considered one of the most important mechanical tests that give the absorption of energy that is required for fracture of the specimen which is given directly from the device. This test was performed according to (ISO-179) at room temperature[10]. Figure (2) shows a standard specimen for impact test.

The impact properties of a material represent its capacity to absorb and dissipate energies used to measure the strength of material under impact or shock loading [11,12]. The impact strength of a material can be measured employing a number of techniques including:-

1. Izod method.

2. Charpy method.

Both Izod and Charpy are used to assess the strength of polymer materials Polymers may exhibit ductile or brittle fracture under impact loading, depending on the temperature, specimen size, strain rate and mode of loading. Both semicrystaline and amorphous polymers are brittle in impact test used to measure the strength of material under high rate of loading (sudden loading). the thermoplastics behave in a brittle manner and have poor impact values will break even when unnotched , cause

the material may show different behavior from load to other. For example, the material may show ductile behavior in tensile test or bending test, while the same material will show brittle behavior in the impact test. Polymers may have transition temperature. At low temperature brittle behavior is observed in an impact test, whereas more ductile behavior is observed at high temperatures, where the chains move more easily .[13]

Impact strength is calculated from the following equation :

…….....(1)

Where:-

Gc: toughness of material (J\ m^2).

Uc: impact energy (J).

A: cross- sectional area of specimen (m^2).

Fracture toughness, which describes the ability of a material containing a crack, to resist fracture, can be expressed as [80]:-

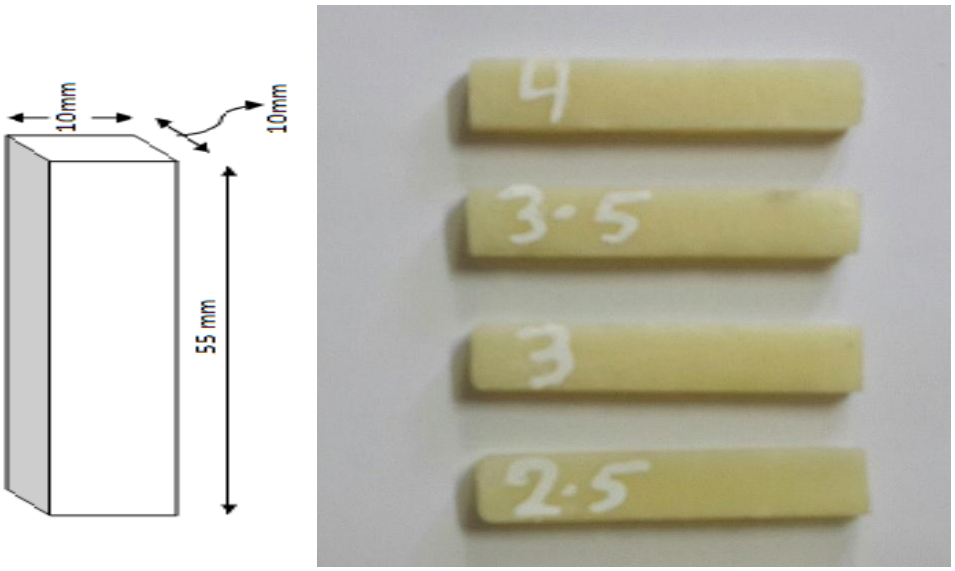
……(2)

where:

Kc: fracture toughness of material (MPa. $m^{1/2}$).

Gc: impact strength of material (J\ m^2).

E: elastic modulus of material (MPa).



Figure(2): the standard specimen according to ISO-179.

Figure (3): Impact test instrument.

VI. RESULTS AND DISCUSSION

Hardness test

Figure (4): a relationship between hardness & density of UP composites before & after post curing

Figure (4) shows that the hardness of unsaturated polyester composites increased with increasing of density before and after post curing (at 40°C). The highest reading was reached after post curing.

Figure (5): a relationship between hardness & density of Epoxy composites before & after post curing .

Figure (5) illustrates that the hardness of epoxy composites increased with increasing of density before and after post curing (at 40°C). The highest reading was reached after post curing .

Figure (6): comparison of hardness between Epoxy and UP composites at room temperature.

Figure (6) reveals that the hardness of epoxy and unsaturated polyester composites increased with increasing of volume fraction of PVC particles at room temperature. The best result was reached in epoxy composites.

Figure (7): comparison of hardness between Epoxy and UP composites after post cured (40°C) .

Figure (7) shows that the hardness of epoxy and unsaturated polyester composites increased with increasing of volume fraction of PVC particles after post curing (at 40°C). The best result was reached in epoxy composites.

Impact test

Figure (8): comparison of impact strength between Epoxy and UP composites at room temperature.

Figure (8 (illustrates that the impact strength of epoxy and unsaturated polyester composites decrease with increasing of volume fraction at room temperature .This is because of the filler particles, which may represent points for a localized stress concentration, from which the failure will begin, so that the composite tends to form a weak structure. Also, an increase in concentration of fillers reduces the ability of matrix to absorb energy, thereby reducing the toughness, so impact energy decreases.

Figure :(9) comparison of impact strength between Epoxy and UP composites after post cured (40°C. (

Figures (9) illustrates that the impact strength of epoxy and unsaturated polyester composites increase with increasing of volume fraction after post curing(at 40°c). This is because the polymers may have transition temperature. At low temperature brittle behavior is observed in an impact test, whereas more ductile behavior is observed at high temperatures, where the chains move more easily.

Figure (10): comparison of impact strength between Epoxy and UP composites at room temperature.

Figure (10) shows that the impact strength of epoxy and unsaturated polyester composites decrease with increasing of density at room temperature.

Figure (11): comparison of impact strength between Epoxy and UP composites after post cured (40°C) .

Figures (11) illustrates that the impact strength of epoxy and unsaturated polyester composites increase with increasing of density after post curing (at 40°c). The highest value was reached in epoxy composites.

Figure (12): comparison of fracture toughness between Epoxy and UP composites at room temperatur

Figure (12 (shows the relationship between the fracture toughness and the volume fraction of filler particles of PVC added to the epoxy and unsaturated polyester resins. The figure illustrates that fracture toughness decrease with increasing volume fraction of PVC filler particles at room temperature .This is due to the dependence of the fracture toughness on the elastic modulus and impact strength, as mentioned before (in equation ,((2) and the impact strength shown a similar behavior to the behavior of the fracture toughness at room temperature as explained .

Figure (13): comparison of fracture toughness between Epoxy and UP composites after post cured (40°C).

Figure (13) indicates that the fracture toughness of epoxy and unsaturated polyester composites increase with increasing of volume fraction of PVC particles after post curing (at 40°c) .

VII. CONCLUSION

The percent of reinforcing and the curing temperature can affect the behavior of composites. The epoxy is the highest in hardness and impact strength than unsaturated polyester composites after reinforcing with thermoplastic material PVC particles . The best impact strength can be reached after post curing at 40°C for 4hr

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